Towards an Information Rich 3D City Model: Virtual NewcastleGateshead GIS Integration

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Abstract: This paper presents an analysis of the emerging issues for the creation of an information rich and geometrically accurate 3D computer model for two adjacent cities, Newcastle upon Tyne and Gateshead, in the north eastern region of the UK - the Virtual NewcastleGateshead (VNG) project. It builds upon earlier research which explores the progress of the VNG project since 2005. The convergence of GIS, BIM, 3D City Modelling as well as other geospatial data sets and technologies are presenting new potentials for urban planning activities and AEC and GIS end users. Successfully integrating 3D geometric data with existing GIS data created by various local authorities with varying software, hardware and manpower capabilities is generating new challenges. However this integration is crucial to achieve an intelligent urban planning system. This paper imparts further findings of a working group set up to explore the possibilities for 3D-GIS integration for the VNG project.

Keywords: 3D city models, urban planning, GIS integration, BIM, Virtual NewcastleGateshead

1. INTRODUCTION

Three dimensional (3D) and VR city models can be simply described as computerized graphical representations or visualizations of any city and their components (Thompson et al 2006). Whyte (2002) emphasizes that the information that exists about a metropolis is hard to comprehend in its totality therefore good representations allow rapid understanding of the relevant features of a data-set.

Research in digital representation of environments, either urban or rural, dates back to the 1990s. Researchers from different disciplines; such as geography, landscape and environmental planning, urban planning, architecture, geo-information science, computer graphics science; have focused on the creation, and usage of digital models and data-sets required for 3D and VR representations, sharing, etc. (Abdul-Rahman, et al., 2006; Batty, 1997; Batty, et al., 1998; Baty et al., 2000; Bishop & Lange, 2005; Bourdakis, 1997; Charlton et al., 2008; Coors & Zipf, 2005; Counsell, Smith, & Richmann, 2006; Danahy, 2005; Day, 1994; Day, Radford ,1998; Delaney, 2000; Discoe, 2005; Dokonal, Martens, 2001; Döllner & Hinrichs, 2000; Döllner et al., 2006; Ervin, 2001; Horne, 2004; Horne et al., 2007; Lange, 2001; Lange, 2011; MacEachren & Brewer, 2004; MacEachren, et al., 1999; Oosterom, et al., 2008; Peng et al., 2002; Pettit, et al., 2008; Pittman, 1992; Pleizier, 2004; Podevyn et al., 2008; Pritchard, 2005; Sinning-Meister, et al., 1996; Skauge, 1995; Thompson et al., 2006; Thompson, Horne 2010, Zlatanova 2000 and many others). It can be said that the role of the most of these digital representations / models is not only for predicting what is going to happen but also for establishing links between stakeholders in order to explain, guide and promote discussion between parties (Epstein, 2008).

The use and functionality of 3D digital city models can be very diverse and it is believed that the new generation of city models will most likely be created by combination of different techniques using various digital technologies to achieve different levels of content (Dokonal 2008). Digital City models can support spatial and functional understanding, raise problem awareness and support collaborative decision-making processes, in areas such as planning and design related activities, infrastructure and facility services, marketing, promotion, tourism, data source for planning applications, surveying, maintenance and development plans, teaching, learning and research activities and historical reconstruction of cities, entertainment related activities, urban information modelling etc. All these administrative tasks in urban management rely on and produce spatial information relevant for decision-making.

The concept of multiple three dimensional (3D) city models existing for one city, each addressing specific applications, is being challenged by the possibility of creating one digital city model which could be utilized for many applications. It is more practical to sustain one city model than to sustain multiple models. Such a model would need to be "information rich" as well as being based upon accurate geometric data. The creation of accurate digital city models is not as complex as it was previously and the increasing availability of "off-the-shelf" 3D model data is making city geometry more accessible, but such data needs to link to existing Geographic Information Systems (GIS) data if a shared collaborative virtual city is the goal (Thompson, Horne 2010). This virtual city would serve as a cross-disciplinary and multifunctional data integration platform and communication media for urban planning and management.

2. 3D MODEL OF NEWCASTLE-GATESHEAD

Newcastle upon Tyne (north of the River Tyne) with a population of 259,536 and area of 11.507 hectares and Gateshead (south of the River Tyne) with a population of 191,151 and area of 14.304 hectares, are neighbouring local authorities in the North East of England. The Virtual NewcastleGateshead (VNG) project investigates the creation of a three-dimensional geometrically accurate computer model for these two local authorities.

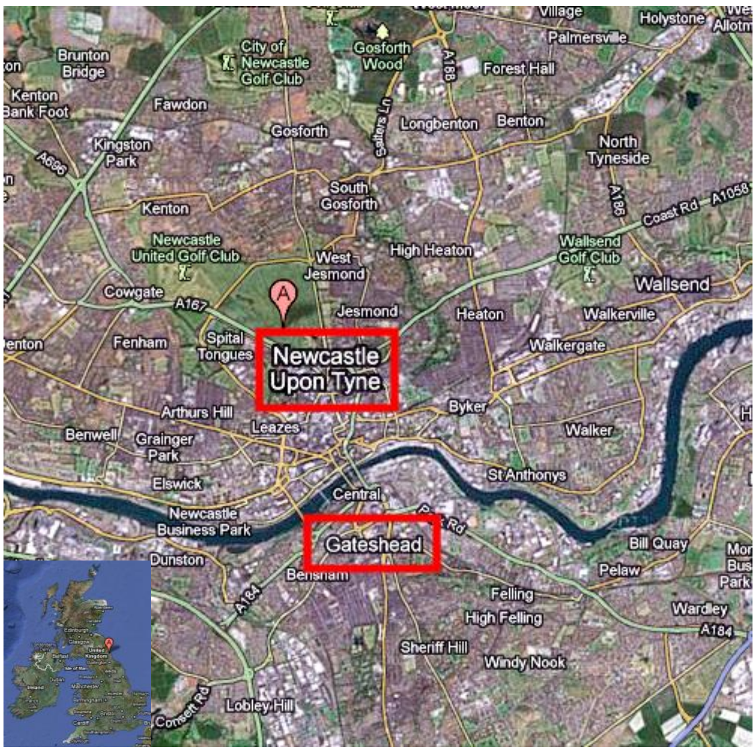


Figure 1 Map Image of Newcastle and Gateshead (Google Maps, 2011)

2.1 Virtual NewcastleGateshead

Since 2005 Northumbria University has been establishing a working relationship with these two local authorities in order to achieve one single authoritative city model that can be used for variety of applications. Horne (2009) indicates that ‘one of the economic drivers for the creation of one definitive, interactive model of both cities’, to bring a solution for the ’jig-saw of 3D models’ (Horne 2009) of a city, is to establish a 3D city model scheme that can be used for different applications, scales, level of detail (LOD) etc.

From the outset it was recognised that this model would require sound management as well as appropriate technical solutions. VNG is directed by a Steering Group composed of members from both local authorities and Northumbria University. The initial aim of VNG, as Horne (2009) explains, was to link to the urban planning process for both cities by creating an accurate massing model with focus on regular model updates, interactive navigation, secure remote access and version control. Other requirements included a www platform for public consultation, GIS integration and support for research and teaching activities. In this way, the longevity of the model could be guaranteed by updating the model with new technologies and standards as both cities develop.

Table 1: Details of VNG Model (Thompson, Horne, 2010)

Details of VNG Model	
Currency	Data captured in 2009 (soon to be updated)
Data capture	Aerial photogrammetry and laser scanning survey techniques (with the view of model to be based upon a database structure to facilitate regular update procedures and efficient management).
Terrain accuracy	0cm-25cm for 70% of points
Terrain	Presenting small and large grassy areas, wooded areas, main and minor roads, railway pathways, bridges, car parks, rivers, water bodies, trees, vertical embankments
Building detail	Initially high detail with features (roof structures, chimneys, pitched roofs, flat roofs, parapets, dormer windows, separation of individual buildings, etc.). Facades, textures added to achieve LODs when needed.
Format	Initially .dwg for the context model, 3dsMax and VR4Max formats used for detailing and interactive presentation purposes. Other formats such SketchUp etc, provided for the councils when they require.

Currently VNG is a 3D massing model of both urban areas, covering 11.5 sq km at present, with a view to extend the coverage approximately to 40 sq km. Aerial photogrammetry and 3D modelling technologies were used to create this model. It is significantly more precise than alternative global visualization solutions such as Google Earth and provides an appropriate tool for planning related activities. Both local authorities have accepted the accuracy of the model data for the purposes of urban planning and have acknowledged the usefulness of 3D computer representations when these have been presented alongside more traditional visualizations, as a part of development proposal submissions (Horne, 2009).

A three-year business model for VNG was produced in 2009 and the first year was designed as a Proof of Concept year. During this stage three working groups were identified to report to the Steering Group; a GIS Integration working group, Modelling Standards and Protocols working group and IT Requirements working group. This paper reports on work of the former group, although there are inevitable overlaps in activities. To date VNG data is being shared between the University and the two local authorities by secure, encrypted file transfer protocol technologies and this is proving appropriate for current usage of the model. Staffing requirements for the model included a dedicated city modeller who acts as a point of contact between the University and urban planners from both cities, as well as other stakeholders, architects and developers who are currently using the model.

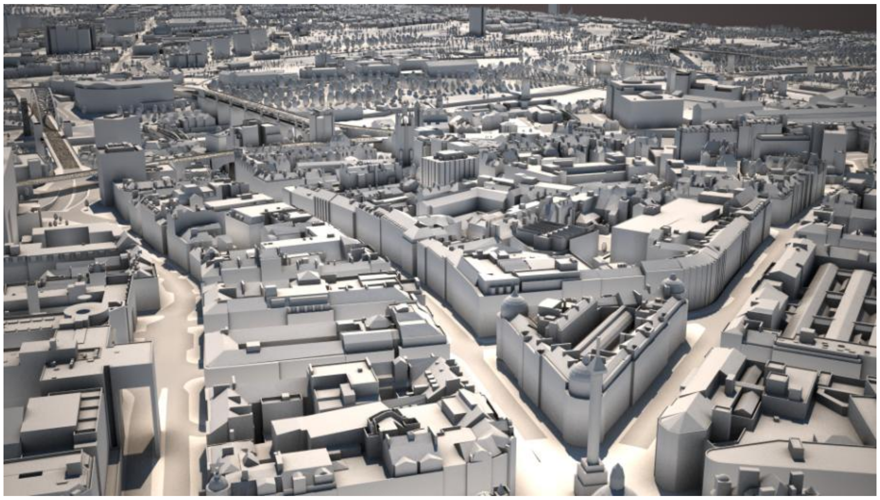


Figure 2 Part of the Virtual NewcastleGateshead Model

Utilizing Virtual NewcastleGateshead

The model is hosted by Northumbria University's School of the Built and Natural Environment and both local authorities are able access the model through secure remote access. By providing a means to accurately assess the impact of design proposals within the urban context, VNG is now being utilized by several major developers. As part of the urban planning process it is offering effective and efficient communication tool by enabling engagement with the local authorities at pre-application stages and throughout the planning application process. Its benefits include much greater accuracy and efficiency for all those involved, by way of greater certainty, quicker decisions, and significant time and cost savings.

a. Image of an area for re-development   b. Model of the same area with suggested new development

Figure 3 VNG being used to assess major new developments

3. INFORMATION RICH VIRTUAL NEWCASTLEGATESHEAD

Although GIS and CAD technologies can represent the same real-world objects, initially they have been created for different domains. CAD software was designed for relatively small geometric models with a focus on visualisation rather than analytical capability. GIS software, in contrast, especially 2D GIS, was primarily designed to deal with geospatial models covering relatively vast areas with spatial analytical functions, but limited visualisation component.

It is widely accepted that two-dimensional maps no longer suffice when communicating 'spatial' ideas to an audience, and the public expect to visualise and query digital data (Evans et al, 2005). VNG is evaluating how an existing 3D city model, which was created initially in CAD format, can be enhanced, using existing GIS, in order to assist communication and decision making processes for urban planners.

3.1 Current Status

Both cities have their own 2D Geographic Information Systems where various data types are being collected and used. In order to utilise these datasets and to create an information rich 3D model the GIS Integration group, established by the VNG Steering Group in February 2010, aimed

- to understand the needs and requirements of the main stakeholders and identify a set of criteria to align with these goals
- to identify tools and technologies oriented towards the integration of GIS data into digital city models
- to screen potential tools and technologies with required functional requirements and performance characteristics
- to recommend a preferred solution, including financial implications and implementation strategy.

The GIS Integration Group has been meeting over the last 18 months and finding out how both local authorities use GIS for on their day-day activities, what different data types they collect and how they utilize this data. Although CAD and GIS resources, both in man power and hardware, vary, both councils use a similar software solution for GIS which is ArcGIS. Other software solutions (ArcGIS, CAD, 3DsMax, SketchUP, BIM tools, LandExplorer etc.) are also utilized by both councils and the University. At the end of VNG's initial proof of concept year Thompson and Lockley (2010) reported that in order to future proof the existing and future data sets, a preferred solution should not be a software solution but rather a standard that would enable storage and data exchange seamlessly.

Data Integration

One of the requirements of the VNG project is to integrate the 3D model of both cities with the GIS datasets of the city councils to enable them to do advanced spatial analyses and visualizations in 3D. Many applications demand an integrated model, requiring harmonisation of domain specific models and modelling methods (Breunig, Zlatanova, 2011). In order to achieve this harmonised model following experiments were carried out.

Work was carried out to determine the capabilities of converting the existing 3D city model to CityGML format. A small part of the model was converted to CityGML by using a SketchUP plugin which was created by University of Applied Sciences Gelsenkirchen, Germany. This process involved importing a cleaned context map in Collada format to SketchUP (7.1) and exporting this file to CityGML. Although the export process was successful, the partial city model was converted as a single building as opposed to identifying every single building on its own in the city model. This was obviously not ideal and different solution was required.

In order to carry out a pilot on data compatibility, data-sets for lighting columns (points), listed buildings (polygons), trees with tree preservation orders and park areas, were received from both councils. As Hijazi et all (2011) explains, to date a certain amount of work has been carried out on integration of IFC, GIS and CityGML. Two approaches have been employed: either transfer geo-data from GIS to BIM; or to transfer BIM data into GIS. However, researchers converted the model data, which was in CAD format, to ESRI Shape File (multipatch) by initially converting to IFC format. This allowed city model and data from the councils (in this instance the trees and lighting columns) to be merged and accessible via ArcGIS (Figure 4).

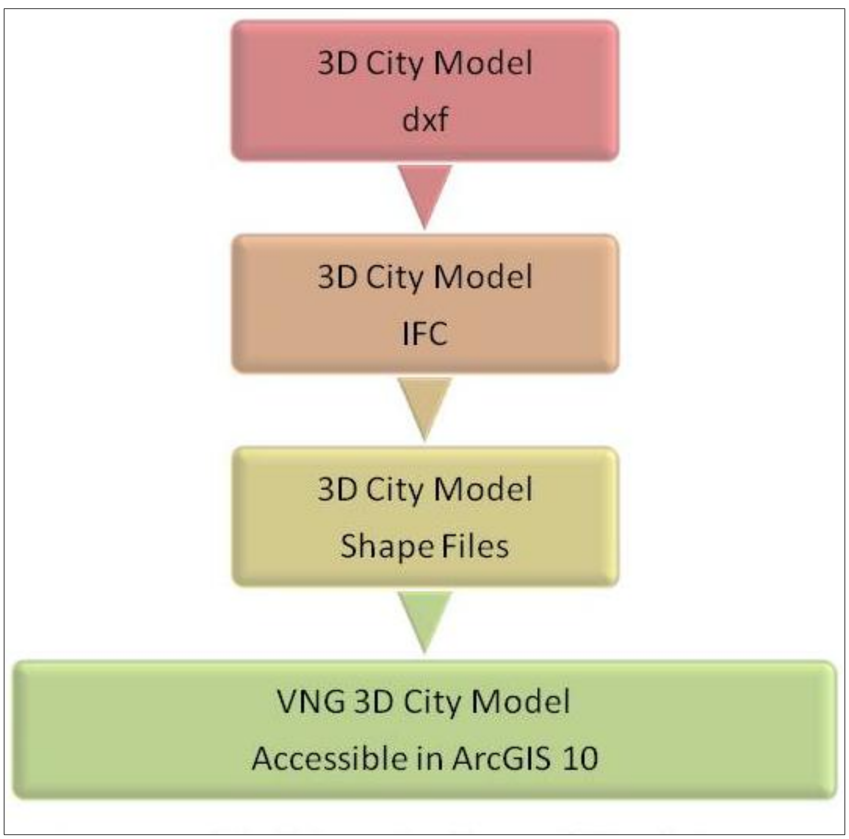
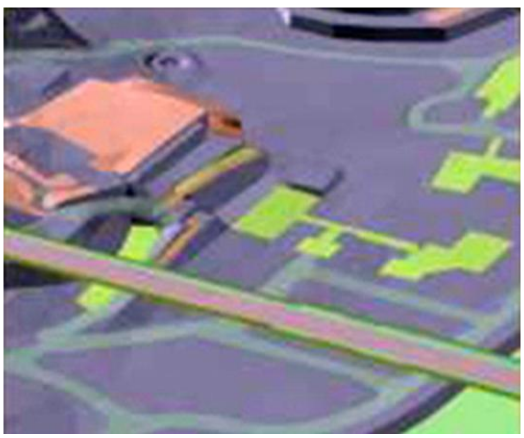


Figure 4 Conversion Process

Industrial Foundation Classes (IFC) is an open standard for storing and interchange of

Building Information Modelling (BIM) data. It has the ability to absorb all the DXF data, which is pure geometry and enables the manipulation of the data in a general way. Moreover, BIM is seen as an essential data source for creating more navigable, interactive and visually realistic information for built environment (Peachavanish, 2006) Using IFC format enables to work not only with geometry but also with semantic information about buildings and other elements. ESRI Shapefile (SHP) is just one of possible outputs producible from the IFC data.

Most of the existing GIS data captured by the councils is two-dimensional and therefore, it lacks height information. Depending on the objects in question, acquiring the third dimension could be expensive and / or time consuming. It is likely that this data already exists, collected by the councils and /or other authorities but methods are being investigated to find how to gather this required data sets from different sources and suppliers, harmonise them and find the most appropriate way to embody them into the current datasets.



a. VNG Terrain in ArcGIS 10

b. VNG Buildings in ArcGIS 10

c. Terrain and Buildings together

d. Data from Councils (lighting columns) in VNG

Figure 5 GIS integration into VNG

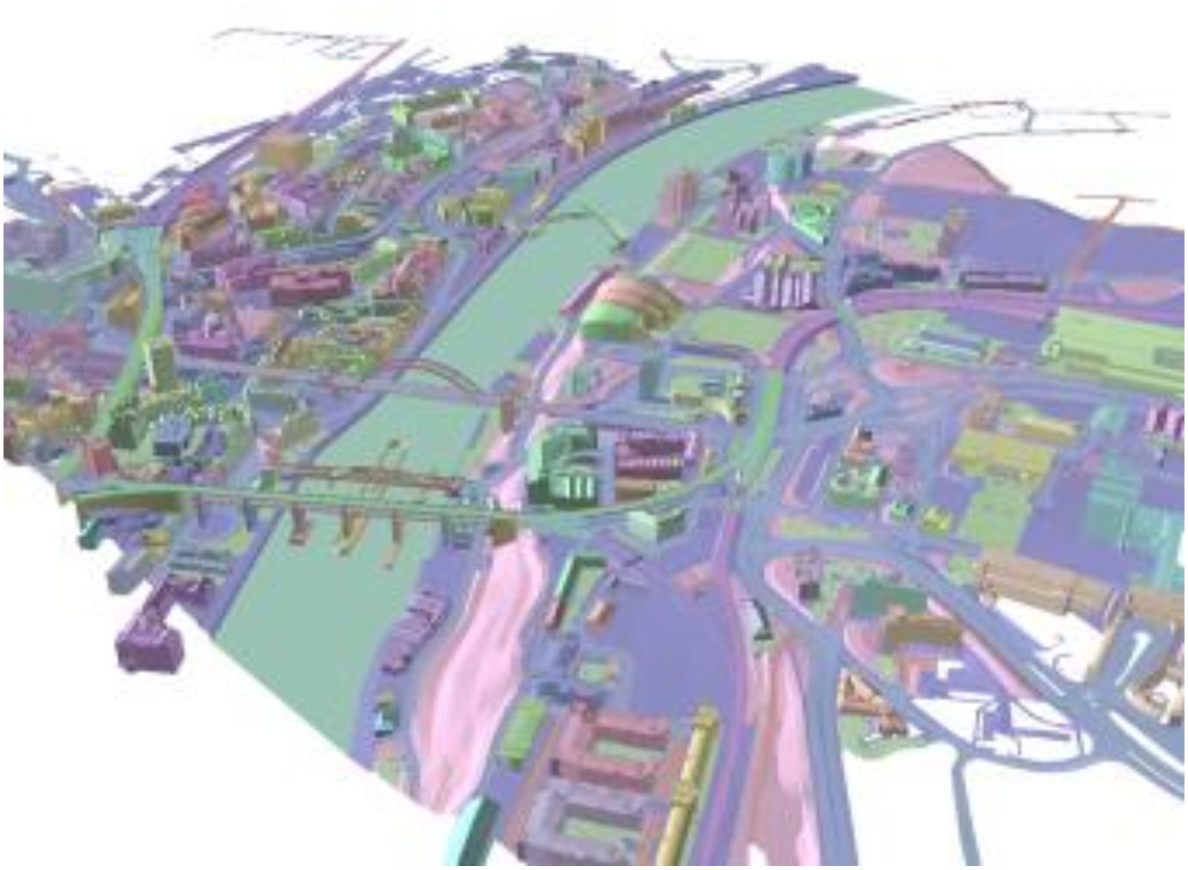


Figure 6 VNG in ArcGIS 10

4. CONCLUSON

On the whole, expectation of 3D GIS is increasing. Researchers are developing solutions to combine geographic and building information in one single model where enquiries can be done. Editing data directly in 3D GIS platforms, more accurate LOS analysis, accurate data conversion between different file formats and database formats (CityGML, IFC) are increasingly becoming important.

This paper has reported on the work in progress in working towards the creation of one information rich digital city model that is hosted by a University and utilised by two neighbouring local authorities in the North East of England. One of the requirements from the stakeholders is the integration of existing GIS data into the 3D model, which is of a geometric level of detail high enough to be used within the urban planning process. The paper has outlined the organisational structure of this project and some of the technical and data acquisition issues currently emerging. As it was noted, there are many aspects of data such as origin of data, data acquisition, and ownership issues still require critical exploration. Solution to these issues will formulate a more sustainable 3D model.

Future work

Breunig and Zlatanova (2011) highlights the new directions in the 3D-geo-database research as 3D data integration, unified modelling of geometry and topology, bridging 2D and 3D worlds, new user interfaces, 3D/4D geo-information systems, evaluation of geo-sensor networks. Correspondingly, the VNG related research certainly would be focusing on 3D data integration, bringing 2D and 3D worlds together and web-based environments, user interfaces for easy access.

Initially VNG GIS Integration working group is planning to provide an interactive model for public participation, based on the VNG data. A pilot project will be carried out in with selected audience and the aim of this project is to provide a platform to involve the public in the planning process, education, and communication about planned projects etc.

The project team is also currently collaborating with Ordnance Survey (OS), the national mapping agency for Great Britain, and is reviewing their latest developments on address products, data that is an essential communication tool with the public as well as government. They are exploring the Feasibility of integrating address and other data into the VNG are being explored. .

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